

HEAVY-METAL POLLUTION OF FOREST ECOSYSTEMS:
EFFECTS ON VEGETATION AND MINERALIZATION OF
ORGANIC MATTER

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Title and subtitle

Heavy-metal pollution of forest ecosystems: effects on vegetation and mineralization of organic matter

Abstract The dissertation (five papers) aims at elucidating (A) the influence of copper and zinc pollution on coniferous-forest vegetation and (B) the influence of motor-exhaust lead on the mineralization of soil organic matter.

(A) Common mosses of mature coniferous forests were the plants most susceptible to the Cu and Zn pollution from a brass foundry. The first signs of decrease in cover were observable where the Cu and Zn concentrations in moss tissues were 4-6 times (Cu) and 2-3 times (Zn) the regional background levels. Where one of the feather mosses, Hylacomium splendens, had Cu and Zn levels as high as 10 times (Cu) and 8 times (Zn) the background level, length and weight of the annual segments were not affected. At about 17 (Cu) and 10 (Zn) times the background levels the segments were 30-33% shorter and 50-65% lighter, however. These metal concentrations approached the survival threshold of the species. Lichens of Cladonia subgen. Cladina were almost as sensitive as the feather mosses but many species of Cladonia subgen. Cladonia, common pioneers, were tolerant. Pohlia nutans was the only ground-layer species that survived in the most heavily polluted area. Epiphytic lichens were reduced in cover and thallus size. Environmental variables modified the response of the vegetation to pollution as revealed by environmental ordination (Reciprocal Averaging). Metal concentrations in plant tissues vary greatly between species. With the aid of interspecies calibration factors, however, several moss and lichen species can when necessary be substituted for the species being used in a survey making it possible to include sites that would otherwise have had to be disregarded owing to lack of sampling material if the survey had been restricted to a single species.

(B) A literature survey (402 references) on the accumulation of and effects of Pb in the terrestrial environment preceded a study on the influence of exhaust Pb on the mineralization of organic matter in spruce mor near a highway. Phosphorus mobilization was disturbed by Pb but any possible influence of Pb on the decomposition and nitrogen-mineralization rates was masked by the pH rise towards the highway.

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The dissertation comprises the following five papers:

- I Folkeson, L. & Kvillner, E. 1983. Influence of copper and zinc pollution on forest vegetation.
- II Bengtson, C., Folkeson, L. & Göransson, A. 1982. Growth reduction and branching frequency in *Hylocomium splendens* near a foundry emitting copper and zinc.
- *Lindbergia* 8: 129-138.
- III Folkeson, L. 1979. Interspecies calibration of heavy-metal concentrations in nine mosses and lichens:
- Applicability to deposition measurements.
- *Water, Air, and Soil Pollution* 11: 253-260.
- IV Folkeson, L. 1976. Bly, särskilt avgasbly, i den terrestra miljön. - Upplagring och ekologiska effekter. Litteraturoversikt. - Statens naturvårdsverk PM 794. Solna. 103 pp.
- V Folkeson, L. 1979. Effekter av tungmetallförorening på nedbrytningsprocesser i skogsmark. V. Avgasbly.
- Statens naturvårdsverk PM 1180. Solna. 39 pp.

Reference to the papers is made by their roman numerals.

INTRODUCTION

During the last decade pollution of the environment by heavy metals from traffic, smelters and other sources has become well documented. The detrimental influence of heavy metals has not only been observed in higher plants and animals but also in less conspicuous organisms. In this dissertation on effects of heavy-metal pollution, the principal interest is directed towards the mosses and lichens of coniferous forests and the activity of soil microorganisms. The main pollutants dealt with are copper, zinc and lead.

EFFECTS ON VEGETATION

The coniferous forest surrounding the present and disused brass foundries at Gusum, SE Sweden, lends itself unusually well to the study of the environmental effects of heavy-metal deposition. Large amounts of copper and zinc, but little SO_2 , are discharged from the low chimneys of the foundry which was built outside the village of Gusum in 1968 to replace the original foundry in the village. The forest surrounding the present and disused foundries is one of the most heavily polluted areas in Sweden as regards heavy metals; the concentration of copper in raw humus close to the new foundry was 400 times as high as the concentrations found at remote sites (6-7 km), and that of zinc 80 times as high.

The effects on vegetation have been studied from several points of view: Paper I describes the effects of copper-zinc pollution on the composition of the vegetation. The aims were to

- investigate the structure of the vegetation in relation to the heavy-metal gradient and to environmental variables
- identify species and groups of species that are sensitive to and tolerant of heavy-metal pollution
- define the degree of pollution at which changes in the occurrence of the common species can first be detected.

The effects were most evident in the ground-layer vegetation. Four stages in its response to the heavy-metal deposition were recognized:

- (1) Common mosses of mature coniferous forests (*Pleurozium schreberi*, *Hylocomium splendens*, *Ptilium crista-castrensis*, *Dicranum polysetum*) were the most sensitive species and were the first to decrease in cover.

- (2) Lichens typical of mature dry forest communities (*Cladonia* subgen. *Cladina*, *C. uncialis*) were reduced in cover.
- (3) Pioneers typical of successional communities (*Cladonia* subgen. *Cladonia*) increased slightly in cover; tolerant mosses retained their cover.
- (4) Even the *Cladonia* lichens and the tolerant mosses, with the exception of *Pohlia nutans*, disappeared.

Epiphytic lichens suffered a reduction in cover. The thalli of *Hypogymnia physodes* were reduced in size.

Field-layer species showed no response apart from a tendency for *Deschampsia flexuosa* to increase in cover towards the foundries.

Environmental variables, such as tree cover, percentage of rock outcrops and moisture of the soil surface, modified the response of the vegetation to pollution as revealed by environmental ordination (Reciprocal Averaging).

A functional aspect is considered in paper II where *Hylocomium splendens* is studied in greater detail. This is one of the commonest mosses in the area. At the same time it is one of the most pollution-sensitive mosses. *Hylocomium splendens* was studied in order to elucidate the influence of copper and zinc pollution on

- the growth of annual segments of the moss
- the branching frequency of the segments and
- the chlorophyll content of the tissue.

The first signs of a decrease in cover were observable where the copper and zinc concentrations in the moss tissue reached values 4-6 times (Cu) and 2-3 times (Zn) the regional background concentrations. In *Hylocomium splendens* fronds with copper and zinc concentrations as high as 10 and 8 times the background level, respectively, segments were 30-33% shorter and 50-65%

lighter, however. These metal concentrations approached the survival threshold of *Hylacomium splendens*. Branching is the most important means of propagation in this moss but it was not affected by pollution; nor was the chlorophyll content.

Paper III concentrates on a technical question in connection with the monitoring of heavy-metal deposition. Pollution is often monitored with the aid of common mosses as sampling material. The high degree of sensitivity of the common mosses to heavy metals is a disadvantage in heavily polluted areas, however. Since the heavy-metal concentrations in plant tissues vary greatly between species, different species cannot be used in the same monitoring survey without resorting to calibration. With the help of interspecies calibration factors, however, several alternative moss and lichen species can when necessary be substituted for the species being used in a survey making it possible to include sites that would otherwise have had to be disregarded owing to lack of sampling material if the survey had been restricted to a single species.

EFFECTS ON MINERALIZATION OF ORGANIC MATTER

A literature survey on lead (paper IV; 402 references) revealed that

- the emission and deposition of exhaust lead are well documented
- lead is accumulated in soil, plants and animals near highways
- lead is efficiently retained in the top soil and its biological availability is low
- the foliar cuticle and the roots of plants impede the uptake of lead
- lead interferes with many physiological and biochemical processes of plants grown in solutions.

However, the survey also revealed a striking lack of information on the effects of exhaust lead on vegetation and microbial processes in the soil.

Paper V reports an investigation on the influence of motor-exhaust lead on the mineralization of organic matter in spruce mor near a highway.

Phosphorus mobilization was found to be disturbed by lead and other pollutants from the traffic. Any possible influence of lead on the rate of decomposition or the rate of nitrogen mineralization was masked by the rise in pH and calcium content of the soil towards the highway, presumably reducing the availability of lead; acidity is known to be one of the factors regulating the solubility of lead in soil (paper IV).

CONCLUDING REMARKS

Lichens, and mosses even more so, were the most susceptible plants near the brass foundries. With regard to the gradual decrease in the cover of the common mature-forest mosses including *Hylocomium splendens* towards the foundries, it is remarkable that the reduction in the length and weight of *H. splendens* segments was only observable in a narrow metal-concentration interval immediately below the threshold level for survival.

Some of the mosses and lichens that were able to tolerate a high metal load are known to be pioneers. Some of them have been reported from SO₂-polluted areas as well. This combination of ability to survive in harsh environments and tolerance of heavy metals as well as of other air pollutants is a noteworthy property of these pioneer plants.

The studies show that also in heavily metal-polluted situations the structure and function of polluted ecosystems are not only regulated by the pollutants but by other environmental factors as well.

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